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Technical Report No. 6

DETERMINATION of BEACH CONDITIONS by means of AERIAL PHOTOGRAPHIC INTERPRETATION

Volume III

PHOTOGRAPHIC GRAY TONES as an INDICATION of the SIZE of BEACH MATERIALS

Cornell University
Office of Naval Research

TECHNICAL REPORT NUMBER 6

DETERMINATION OF BEACH CONDITIONS

by means of

AERIAL PHOTOGRAPHIC INTERPRETATION

VOLUME III

PHOTOGRAPHIC GRAY TONES

as an INDICATION of the

SIZE OF BEACH MATERIALS

In connection with
a contract between:

Amphibious Branch, Office of Naval Research — School of Civil Engineering, Cornell University

U.S. Naval Photographic Interpretation Center, Monitor

Executed by the

Cornell Center for Integrated Aerial Photographic Studies

Beach Accessibility and Trafficability

Project No. NR 257 001

Contract N6onr, Task Order #11

by

D. R. Lueder

D. J. Belcher, Director

June, 1954

Ithaca, New York

KEY TO TECHNICAL REPORT NUMBER 6

Technical Report Number 6 is divided into five Volumes. The titles of these Volumes are as follows:

- Volume I - Relations Between Beach Features and Beach Conditions.
- Volume II - Variation and Stability of Beach Features (including an Appendix on Wave Tank Tests).
- Volume III - Photographic Gray Tones as an Indication of the Size of Beach Materials.
- Volume IV - The Cone Penetrometer as an Index of Beach Supporting Capacity (Moisture, Density and Grain-Size Relations).
- Volume V - A Method for Estimating Beach Trafficability from Aerial Photographs.

ACKNOWLEDGMENTS

The author wishes to express his appreciation for the cooperation, aid and helpful opinions provided by Colonel J. P. Stafford, U.S.M.C. and Major Carl Hill, U.S.M.C. both of the Amphibious Branch, Office of Naval Research and by Mr. Page Truesdell of the Naval Photographic Interpretation Center. The administration, establishment - and continuance - of this program is due, in no small way, to the efforts of these men.

The fine work of Mr. Gunnar Simonsson on routine densitometric measurements is also gratefully acknowledged. Finally, credit belongs to Miss Barbara Freeman for completion of the tedious task of report preparation and assembly.

CONTENTS

LIST OF FIGURES

CAUTIONARY NOTE

It is the ultimate objective of this research program to investigate and report upon a method for estimating beach trafficability by means of aerial photographic analysis. Trafficability is a tenuous term. For the purpose of this study, it has been considered to be related to:

1. Slope of beach
2. Bearing capacity of beach

Outside factors such as vehicle types, loads and tire pressures; driver abilities and surf conditions; and multiple pass effects were not considered.*

Two things must be emphasized. First, the trafficability diagram appearing as Figure 2 of Volume I and mentioned thereafter, relates slope and penetration values and assigns any given beach to one of five classes. THIS DIAGRAM IS INDICATIVE ONLY AND SHOULD NOT BE USED WITHOUT VERIFICATION OR MODIFICATION IN THE LIGHT OF CURRENT OPERATIONAL TECHNIQUES.

Secondly, the index of beach sand bearing capacity chosen by the authors for use in this investigation was constant weight penetration. The authors believe this to be a reasonable and acceptable index.** However, THE SIGNIFICANCE OF THE INDEX WITH RESPECT TO ACTUAL OPERATIONS MUST BE EVALUATED BY USING AGENCIES.

These statements emphasize the necessity for studies which will correlate penetrations with operating conditions. Only by this means can the research results discussed in Technical Report #6 by utilized to their fullest extent.

---

* See Progress Report #1, "Relations Between Beach Features Visible on Airphotos and Beach Trafficability".

** See Volume IV (Key).

LIST OF ABBREVIATIONS

AFS	-	Average foreshore slope (See Appendix A)
APR	-	Average penetration reading
Bs	-	Backshore
d	-	Divergence (See Figure 10)
D_{50}	-	Median grain-size (See Figure 10 and Appendix A)
Dec D_{50}	-	Decimal median grain-size (See Figure 10)
DFs	-	Drying foreshore
Fs	-	Foreshore
Fs MSLW	-	Foreshore mean-sea-level width (See Figure 9b and Appendix A)
PR	-	Penetration readings
WFs	-	Wetted foreshore

SECTION I

INTRODUCTION

SCOPE OF VOLUME

This Volume is concerned with the factual aspects of one subdivision of a current research project conducted for the Amphibious Branch, Office of Naval Research. It describes the results obtained from densitometric analyses of gray-tone patterns appearing on aerial photographs of certain sand beaches composed of various predominant grain-sizes and slopes.

A series of conclusions appears as SECTION III. These conclusions are based, for the most part, on the data, analyses, and discussions included herein. Consequently, they represent the specific conclusions of the report -- not conclusions of the complete research program.

Final conclusions of the complete research program will be limited in nature. Only those factual aspects that are pertinent to the ultimate objectives of the program will appear. These will be published in Volume V.

ULTIMATE OBJECTIVES OF

COMPLETE RESEARCH PROGRAM

The ultimate objectives of the complete research program are:

1. The presentation of relations between physical features (visible on aerial photographs) that are associated with beaches, and the trafficability of beaches.*

2. The formulation, based upon such relations, of a method for estimating the trafficability conditions of beaches from aerial photographs.

---

* See CAUTIONARY NOTE

PROBLEMS OF RESEARCH

There are numerous features associated with beaches that may have some relation to trafficability and that can also be seen on aerial photographs. These are:

1. Details of beach profile (width, slope, cusps, scarps)
2. Wave and surf features (length, frequency, shape, direction, refraction, breaker patterns)
3. Gray tones (beach sands, moisture holding capacity, turbidity stains, depth differences)
4. Environmental features (offshore and onshore protection, river mouths, sources of supply, indications of littoral current flow)
5. Miscellaneous features (current ripples, bars)

These features, as well as trafficability itself, reflect the interaction of numerous variables. The variables are:

1. First order variables (independent)
    a. Location and variations in winds
    b. Environment
        (1) Protective underwater features
        (2) Protective surface features
        (3) River and tidal mouths
        (4) Littoral currents
        (5) Geological sources and types of materials that contribute to beach

(6) General offshore slope

c. Tides

2. Second order variables (dependent upon first order)

a. Wave characteristics and variations

3. Third order variables (dependent upon first and second order)

a. Variations in local offshore slopes, bars and local material supplies.

None of these variables can be controlled by any normal means. Few can be evaluated easily by instrumental devices. Consequently, it is difficult to relate specific beach features to the variable or combination of variables that produce them. To satisfy the practical requirements of the project, it was decided to subordinate the relations between beach features and their causative variables and to emphasize direct relations between features and trafficability conditions.

SCHEME OF COMPLETE RESEARCH PROGRAM (CURRENT)

The current program was subdivided into various separate activities. This was done in an attempt to circumvent some of the difficulties previously discussed by varying the direction of attack.

The subdivisions established were as follows:

1. Routine Beach Observations

   The collection of routine observations at permanent beach stations for a reasonable period of time. This phase was designed to give information concerning the changes of beach features and conditions on beaches of various types over a period of time. This phase, since it was concerned with time, was expected to throw some light on the relative importance of causative variables such as waves, material characteristics, etc..

2. Empirical Beach Survey

   The collection and analysis of information concerning the physical and penetrometer profiles and the sand characteristics of various beaches picked at random. This phase, since it neglected time, waves and environment, was designed to provide relations between visible features and trafficability conditions regardless of any causative variable except beach materials.

3. Penetration - Compaction Studies

   A small laboratory study of the relations between penetrometer readings, compaction and grain characteristics.

4. Wave Tank Investigation

   A small investigation of general relations between slope, slope variations and relative stability as affected by changes in the characteristics of waves acting upon materials of different grain-size.

5. GRAY TONE STUDIES (SUBJECT OF THIS REPORT)

   A DENSITOMETRIC STUDY OF GRAY TONES ON THE BEACH AS INDICATORS OF PREDOMINANT SIZES OF BEACH MATERIALS AND THEIR RELATIVE FIRMNESS.

Each of these subdivisions will be treated in other reports.

SECTION II

SIGNIFICANCE OF GRAY TONE PATTERNS ON SAND BEACHES

GENERAL

In airphoto interpretation, as practiced by experienced specialists, great significance is often attributed to gray tones. A so-called "black and white" airphoto is composed of a great variety of gray tones, ranging from near black to near white. These tones reflect many things: the film's registration of actual soil colors; the reflective characteristics of various ground covers; and the moisture content of the soil.

To the interpreter, the latter indication is of greatest value in forming an estimate of ground conditions. It will be noticed on an airphoto that lakes, rivers, or deep bodies of clean water appear as black or very dark gray. Deposits of clean, dry sand appear white or near white. In general, it may be said that dry materials may be expected to display light tones and wet materials, dark tones. The degree of tone, therefore, may be expected to indicate the general moisture content of the soil.

The significance of gray tones does not end with this elementary conclusion. The characteristics of the boundary between two adjacent tones also have considerable significance. Consider two deposits, one of pure sand and one of "pure clay", both standing at the same slope and in contact with the groundwater table at the same elevation. The situation is shown in Figure 1a.

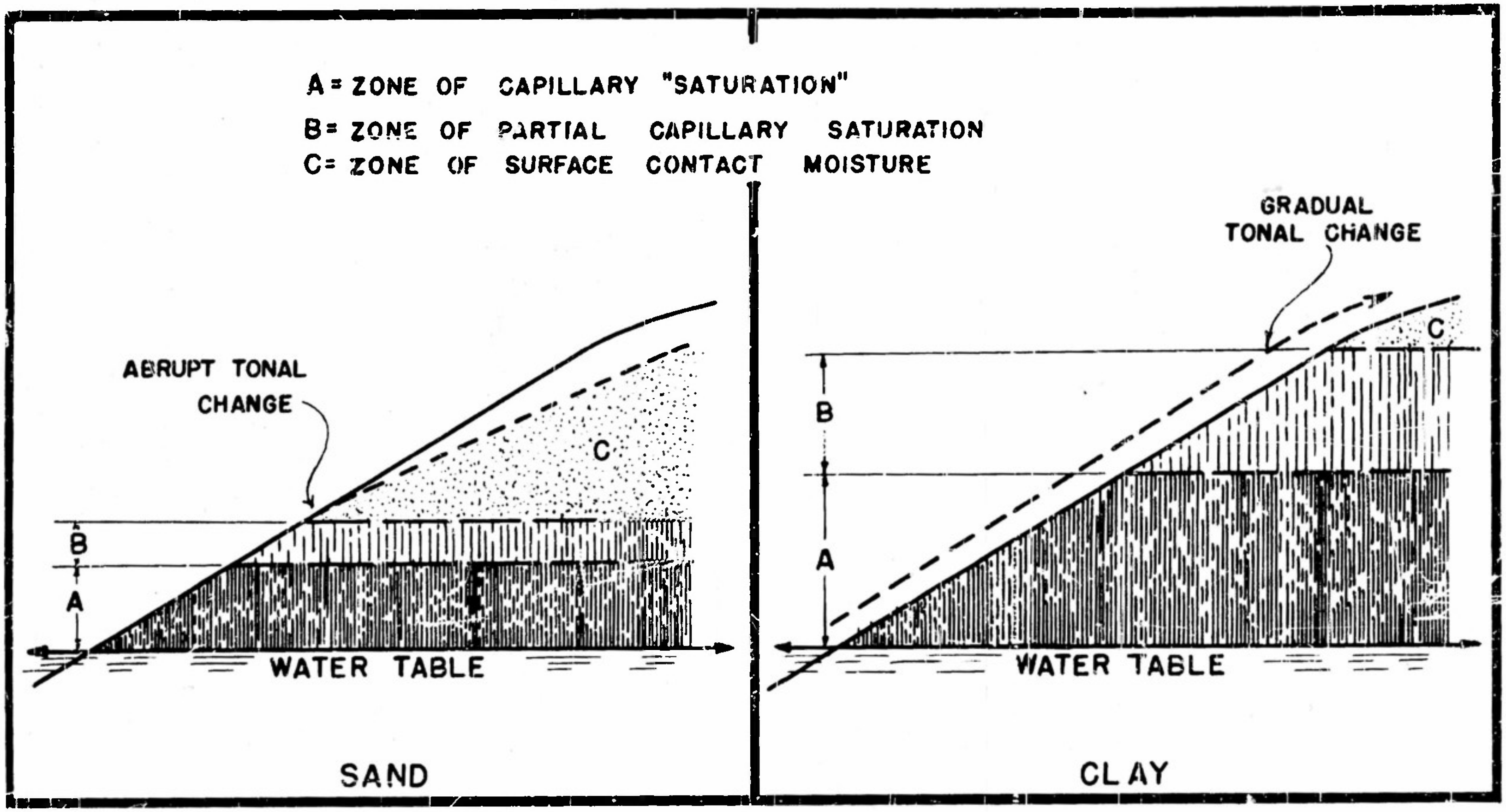

FIGURE 1A

COMPARATIVE MOISTURE ZONES IN SANDS AND CLAYS

Because of capillary forces, ground water is drawn upward, above the ground-water table, through the soil spaces. Because of this process, two zones are created*, one of capillary "saturation" and one of partial capillary saturation. The extent and perfection of these zones depends primarily upon the characteristics of the soil under consideration. The soil characteristic of major importance is the representative range of material grain-sizes. The smaller the predominant grain-sizes, the greater the potentiality for capillary rise. Therefore, in general, sands (coarse-grained) may be expected to have a narrow zone of capillary effect, while clays (fine-grained) may be expected to have rather broad zones. Furthermore, because of the grain-sizes involved, the zones of capillary and partial capillary saturation in sands may be expected to be rather constant in character, of relatively small vertical extent and characterized by an abrupt stop. The analogous zones in clays may be expected to vary somewhat more, be of greater vertical extent and characterized by an indefinite upper boundary.

In summation, the zone above the ground-water table in sands will be relatively narrow, of relatively constant dark tone and characterized by a relatively abrupt tone break. The same zone in clays may be expected to be relatively broad, of

* The conception of these zones was suggested by Karl Terzaghi. He also included a zone of contact moisture extending from the ground surface to the zone of partial capillary saturation. This zone is neglected in the following discussion.

gradually changing tone, and characterized by a zone of gradual tone diminishment. This situation is shown schematically by Figure 1a.

The practical significance of these differences of tone, tone boundary and tone extent lies in their evident value as indicators of soil texture, i.e. predominant grain-sizes.

As explained in Volumes I, II and IV of this report, a knowledge of predominant grain-sizes is of considerable value in making an estimate of beach trafficability.

When the current phase of this general research project was started, in 1953, it was decided to investigate the possibility of relating the tone pattern shown on a beach to its predominant grain-sizes. It was believed, intuitively, that all conditions being equal, a beach composed of coarse sand would have a narrow abrupt tone change at the waterline, while one composed of fine sand would have a broader, gentler change.

It was realized that, due to tidal fluctuations, wave changes, slope variations and debris accumulations, the patterns would be subject to some variation, but that, by proper interpretation, the typical pattern for various grain-size classes could be distinguished.

In some respects, beaches seemed to provide an excellent site for gray tone investigations. No vegetative cover required consideration. The soil texture was limited to sand sizes, composed predominantly of quartz and/or feldspar*. Slopes,

* See Volume I of this report.

and therefore, reflection, varied within a fairly narrow range. The beaches were bounded by two zones of possible relatively constant characteristics, one being the dry backshore and the other being the almost completely saturated wetted foreshore. These zones provided possible upper and lower limits to gray tone variation.

Consequently, it was felt that the probably advantages of a gray tone study outweighed the disadvantages.

At this point, there were two possible methods of approach, one qualitative and the other quantitative. The qualitative approach involved the examination of many airphotos and a general correlation of their tone patterns with grain-size classes. This method was discarded because of the lack of a base for comparison, the possible diversity of qualitative opinion and the neglect of scientific approach. It was realized that the ultimate user of any information obtained, namely the military interpreter, would be supplied only qualitative information, but it was felt that there were definite advantages in backing up his qualitative information with quantitative data.

Accordingly, a quantitative approach was adopted. Originally, the method contemplated the simultaneous execution of aerial photography, physical profiling and material sampling on a variety of beaches. This was to be followed by controlled development of the aerial films to something approaching a constant gamma, and measurement, with a transmission micro-densitometer, of the tones across the beach parallel to the physical profile. It was hoped that comparative quantitative data pertaining to density slopes, adjacent contrasts, etc. might thereby be obtained.

This ambitious program broke down for a variety of reasons, and many compromises and revisions had to be made*. Further, the quantitative data that was finally usable was reduced severely. However, results were sufficiently good to meet some of the project objectives. A discussion of these results follows.

---

* A description of the methods used appears in Appendix A.

DATA PRESENTATION

The discussion of results is quite brief, the major items of interest being the density plots themselves. On the following pages, selected density plots, physical profiles, and beach pictures appear as Figures 3 to 14.

The physical profiles included in these figures are actual profiles taken on the beach at the indicated time, using rod and level as described in Appendix A, Volume II. Samples of beach sand were taken at the same time.

The small sections of vertical aerial photographs included in Figures 3 to 14 show the sections of beach upon which the profiles were taken. Micro-density plots were completed along a line roughly perpendicular to the waterline, beginning at the small dot appearing on the photographic prints. The position of this dot corresponded approximately to the reference point for ground observations. Letters appearing on the print indicate reference points that were used to refer all gray tones to the same range of relative densities for comparative purposes.*

The density plot shows coordinate values of relative diffuse transmission density and distance from the reference point in feet. All absolute transmission densities were converted to relative densities in accordance with the method described in Appendix B. Therefore, regardless of the condi-

* See Appendix B.

tions of exposure and development, density plots from any one beach on various days could be compared quantitatively*. Density plots from different beaches could also be compared depending upon the availability of reliable gamma information*.

The density plots shown are graphically averaged plots. The actual micro-densitometric plots were smoothed out. A comparison between typical plots appears as Figure 2.

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* See Appendix B.

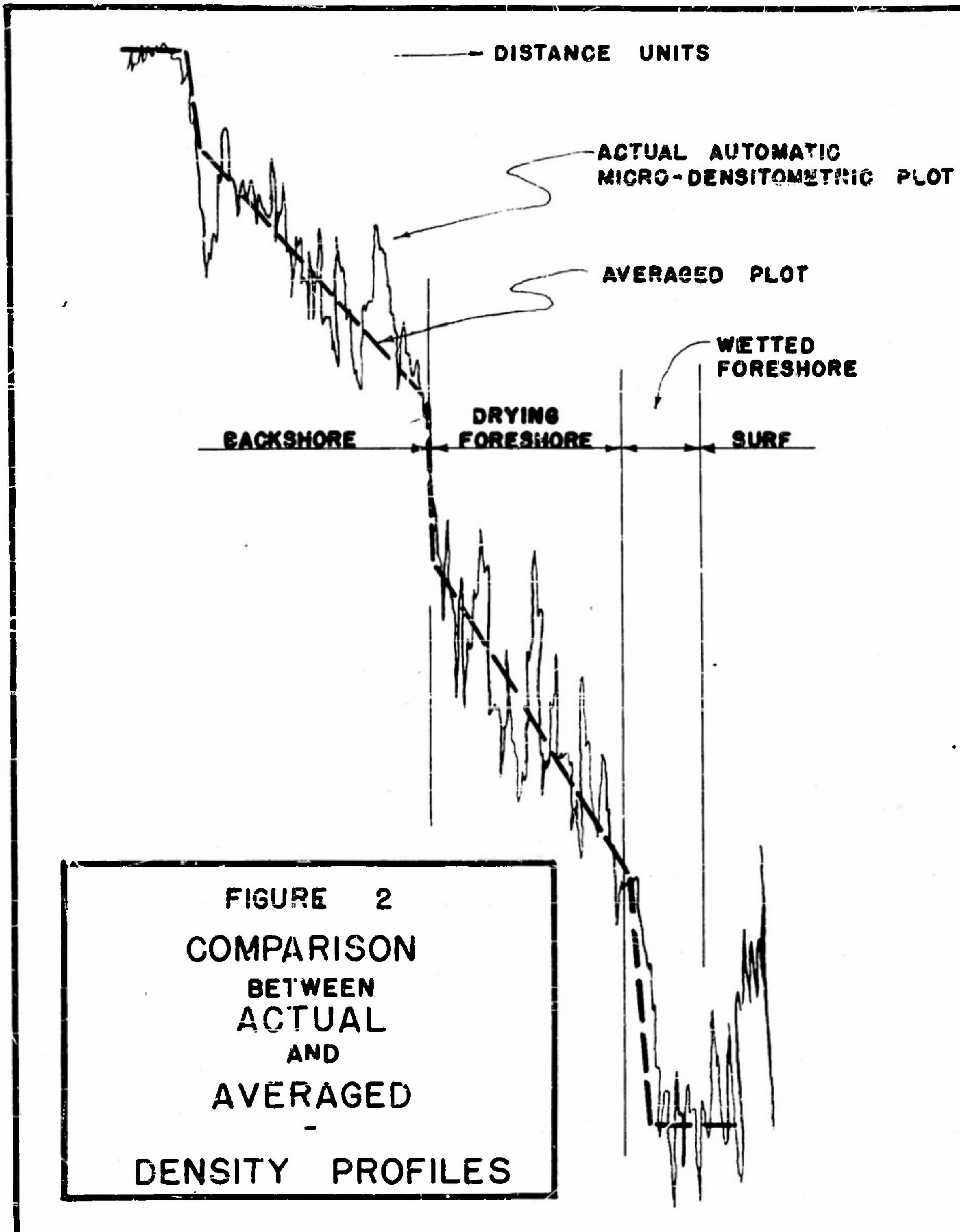


FIGURE 2

COMPARISON BETWEEN ACTUAL AND AVERAGED - DENSITY PROFILES

GRAY-TONE PATTERNS OF COARSE SAND BEACHES

During the completion of a series of laboratory tests designed to explore the moisture-density-penetration relations of various beach sands,* it was found that coarse sands ($D_{50} >$ 0.5mm.) would not retain moisture at their surface in excess of 6%-8% (20-30% saturation) regardless of the amount originally added (until complete saturation, of course).

This experimental fact provides a key to the probable gray-tone pattern characteristic of coarse sand beaches. Logically, it should consist of:**

1. A fairly uniform, light-toned area indicating the backshore with its negligible surface moisture contents (0-2%)
2. A band, usually narrow but occasionally broad, of rapidly increasing darkness, indicating a rapid increase in moisture content (to 6-8%) at the backshore - foreshore boundary
3. A relatively broad band, of fairly uniform tone, only slightly darker than the backshore, indicating the drying foreshore with its fairly constant maximum surface moisture contents (6-8%)

---

* Discussed in Volume I of this report.

** Erratic tones due to debris, seaweed, local low-spots, etc.. are neglected.

4. A very narrow band of rapidly darkening tone (often an abrupt darkening) indicating the sudden change from a near dry to a nearly saturated condition (80-100%) at the drying foreshore-wetted foreshore boundary.

5. A band, of variable width, having a fairly uniform dark tone indicative of the wetted foreshore with its nearly saturated sand (80-100%) and for substantial expanse of free water surface.

Patterns similar to these were actually found to be typical of the coarse beaches for which data was available. Figures 3 to 7 show typical density plots with their accompanying photographs and physical profiles. Figure 8 is a schematic representation of an idealized density (gray-tone) profile.

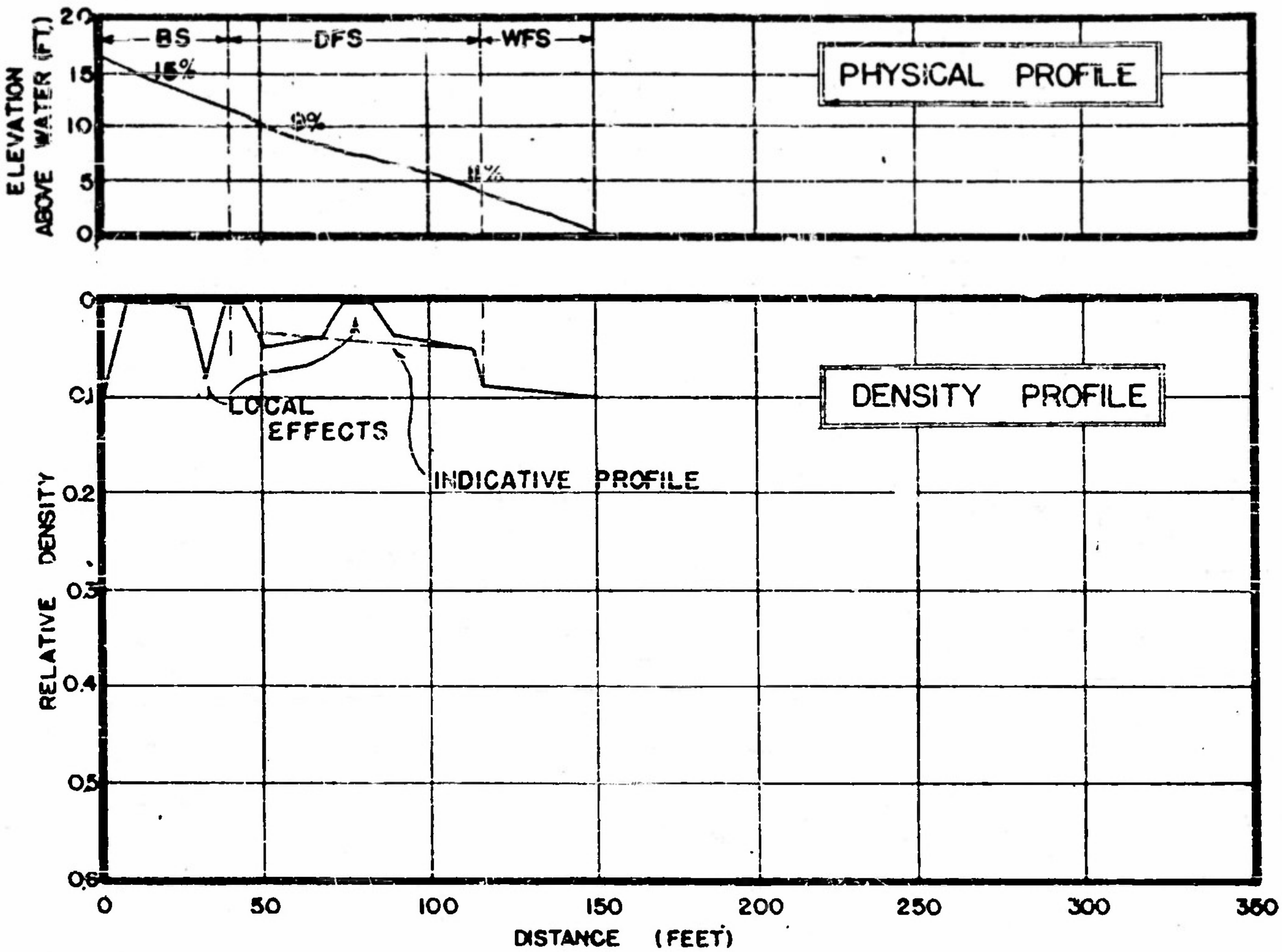
The pattern may be complicated by the occurrence of cusps, slope breaks, or frequent high waves. Some of these effects are shown in Figures 3 to 7. The effect of high waves is well shown in Figure 9.

In summation, the gray-tone pattern characteristic of the drying foreshore on coarse sand beaches consists of two tone-bands,* one usually narrow and next to the backshore, the other

---

* This pattern is specifically characteristic below mid-tide stage. The pattern is generally invisible at high tide stages. Also, when there are frequent high waves separated by periods of lower waves, there may be an additional dark land near the waterline. See Figure 8.

relatively broad and extending to the wetted foreshore. The first band shows a slight amount of darkening. The second band is relatively uniform. Neither band is exceptionally darker than the backshore.



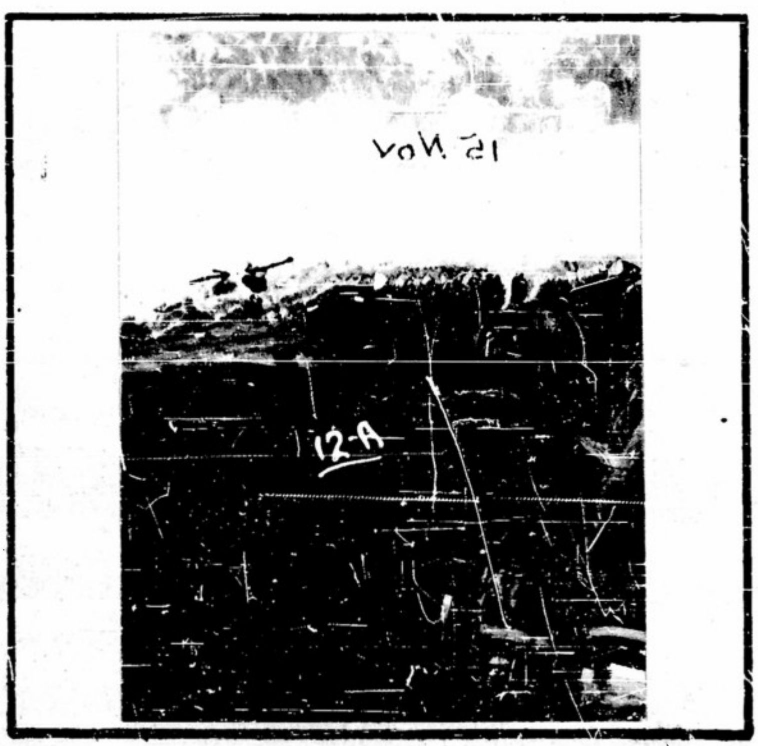


FIGURE 3

BEACH NO. 12 A
DATE 15 NOV. '53
SCALE: 1:2500
D_{50} (DEC.): 1.88

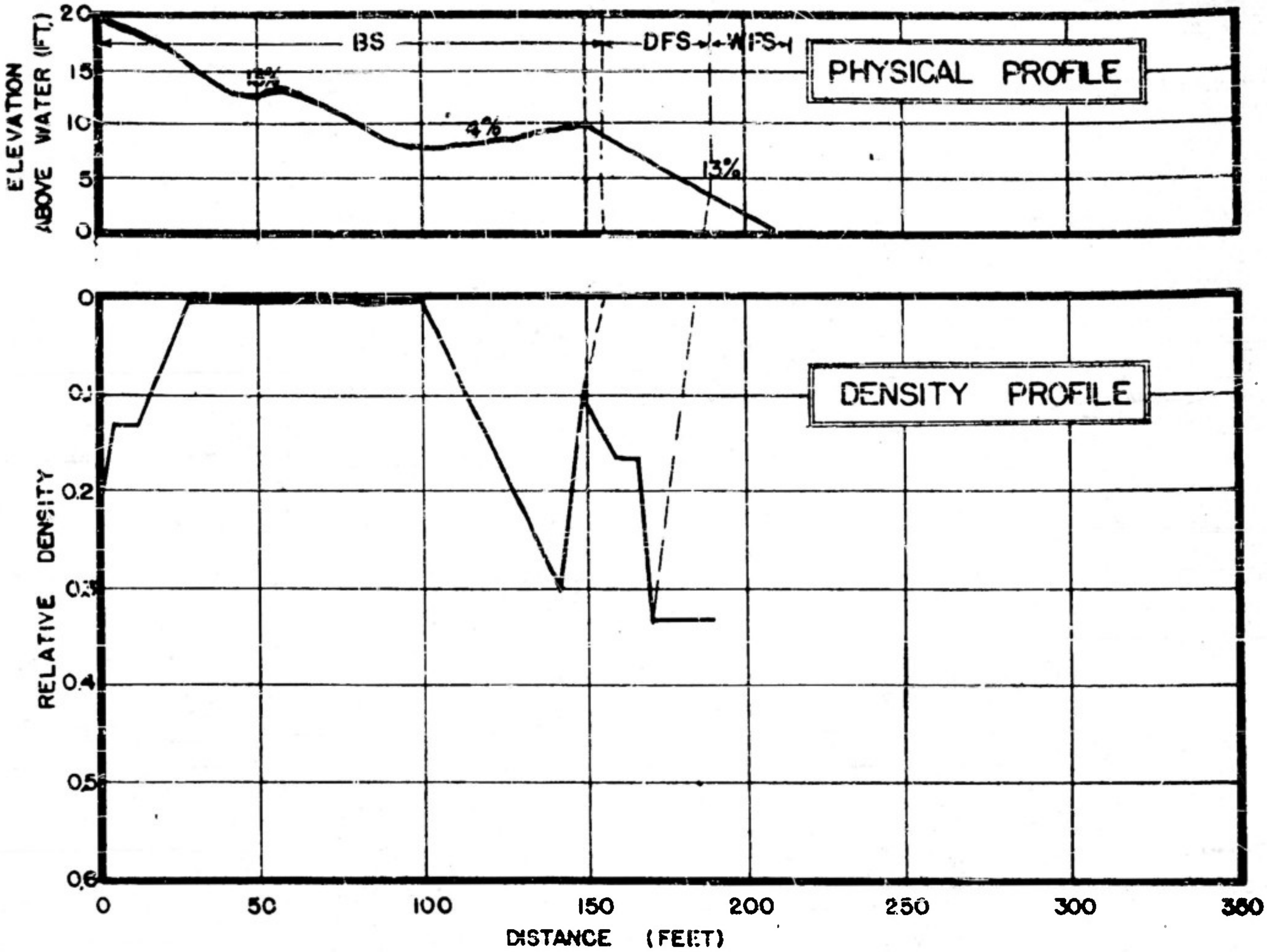
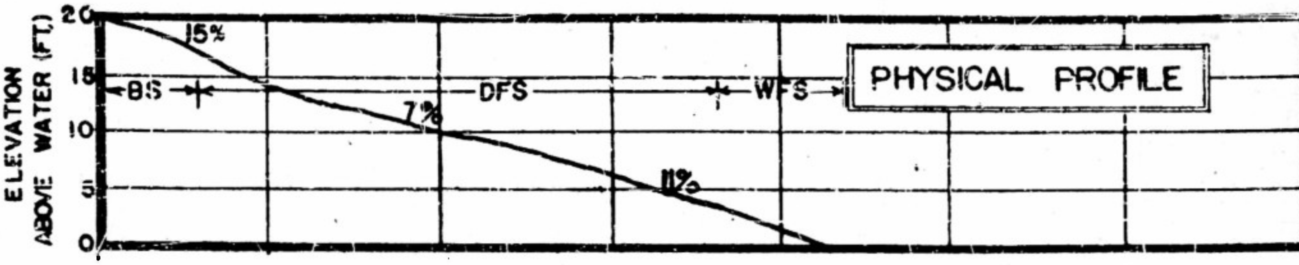
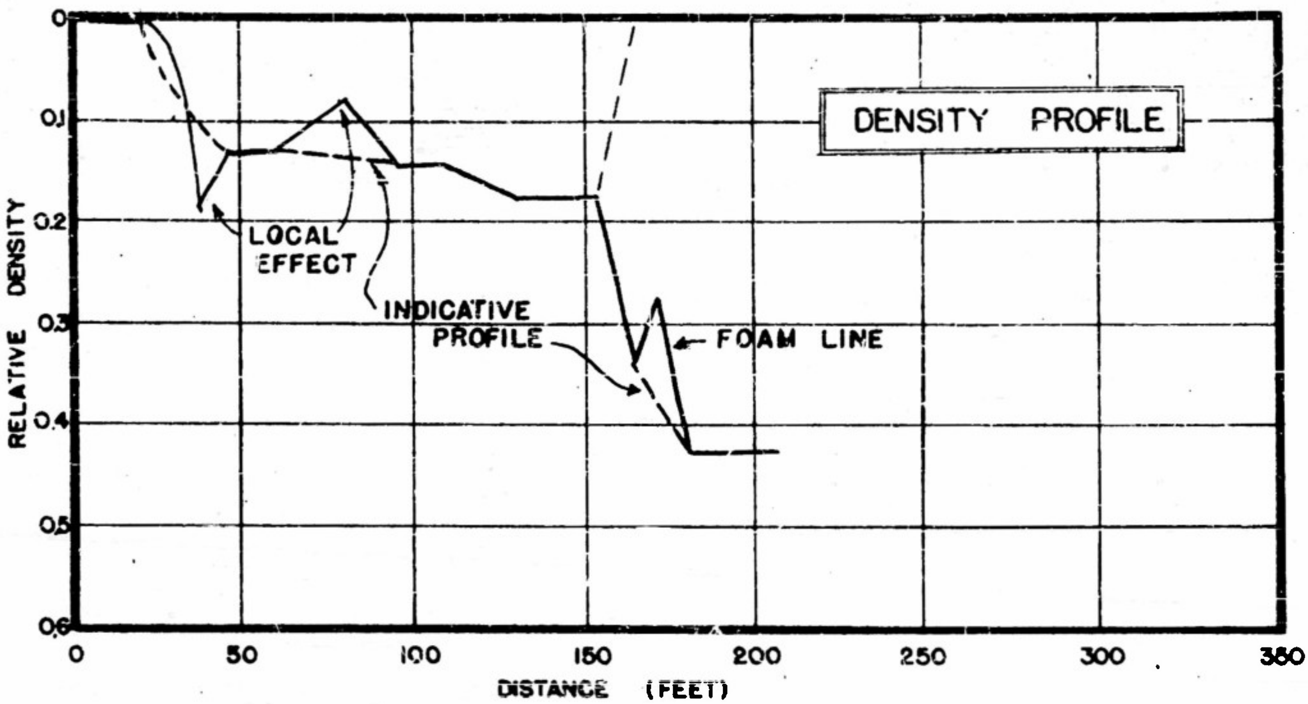


FIGURE 4

BEACH NO.	12 A
DATE	4 SEP. 54
SCALE:	1:2500
D_{50}(DEC.):	1:58





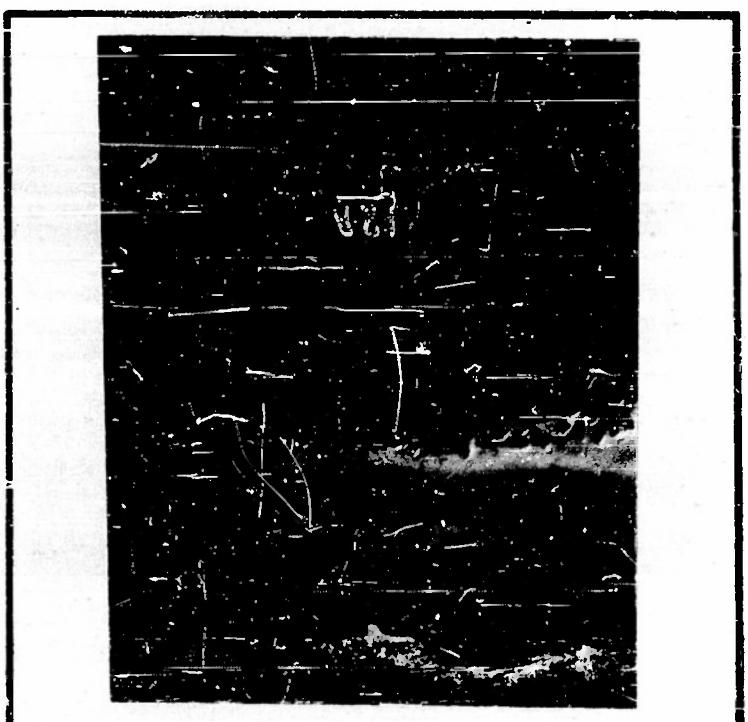
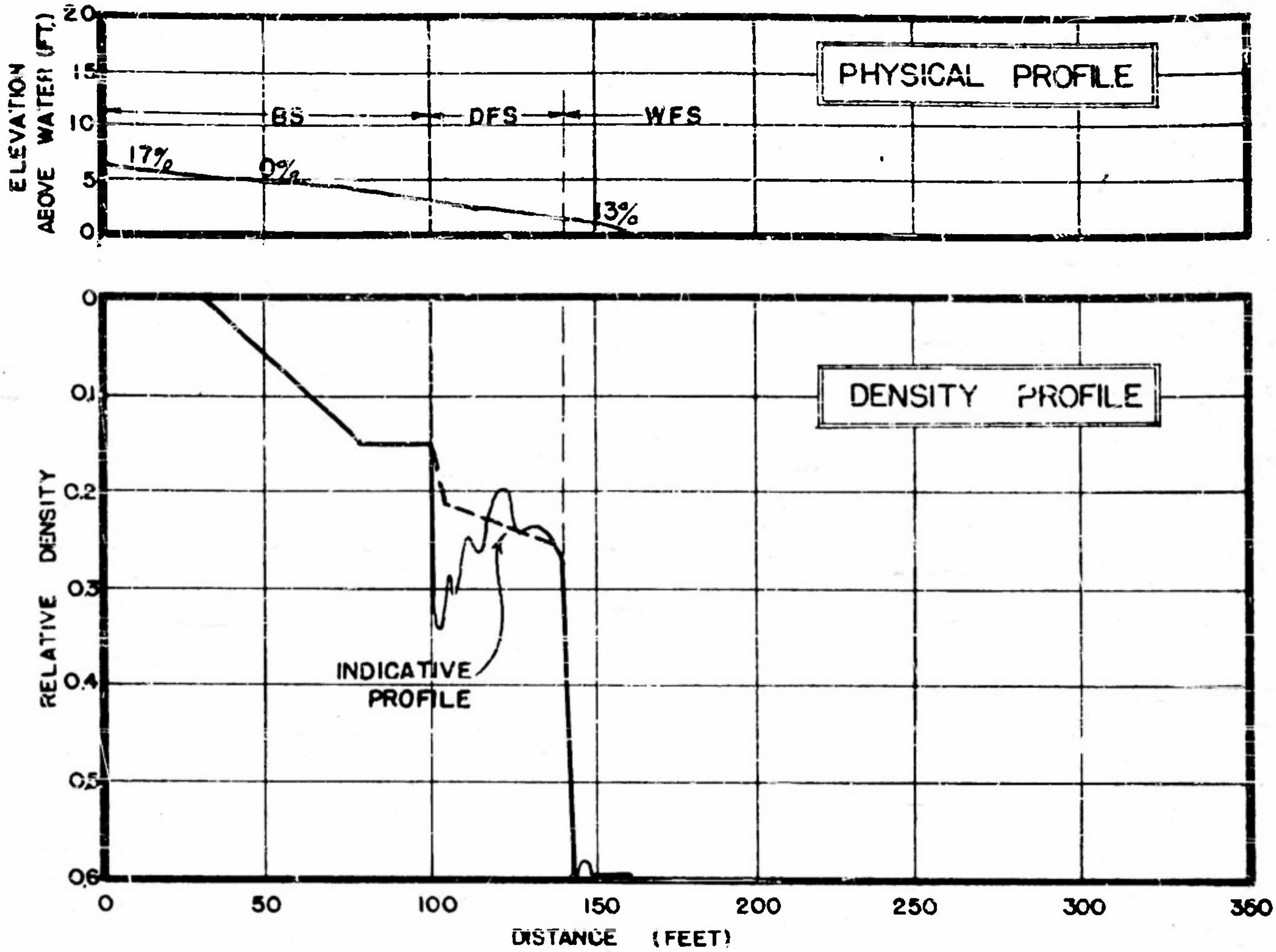


FIGURE 5

BEACH NO.	12 A
DATE	18 NOV. 53
SCALE:	1:2500
D_{50}(DEC.):	1,65



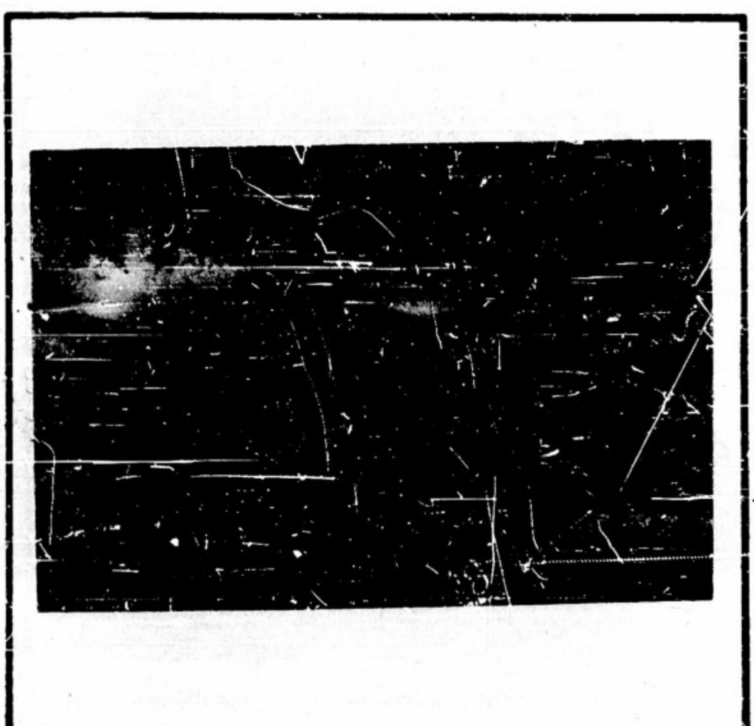


FIGURE 6

BEACH NO.	18
DATE	24 SEP 53
SCALE:	1:2500
D_{50}(DEC.):	1.64

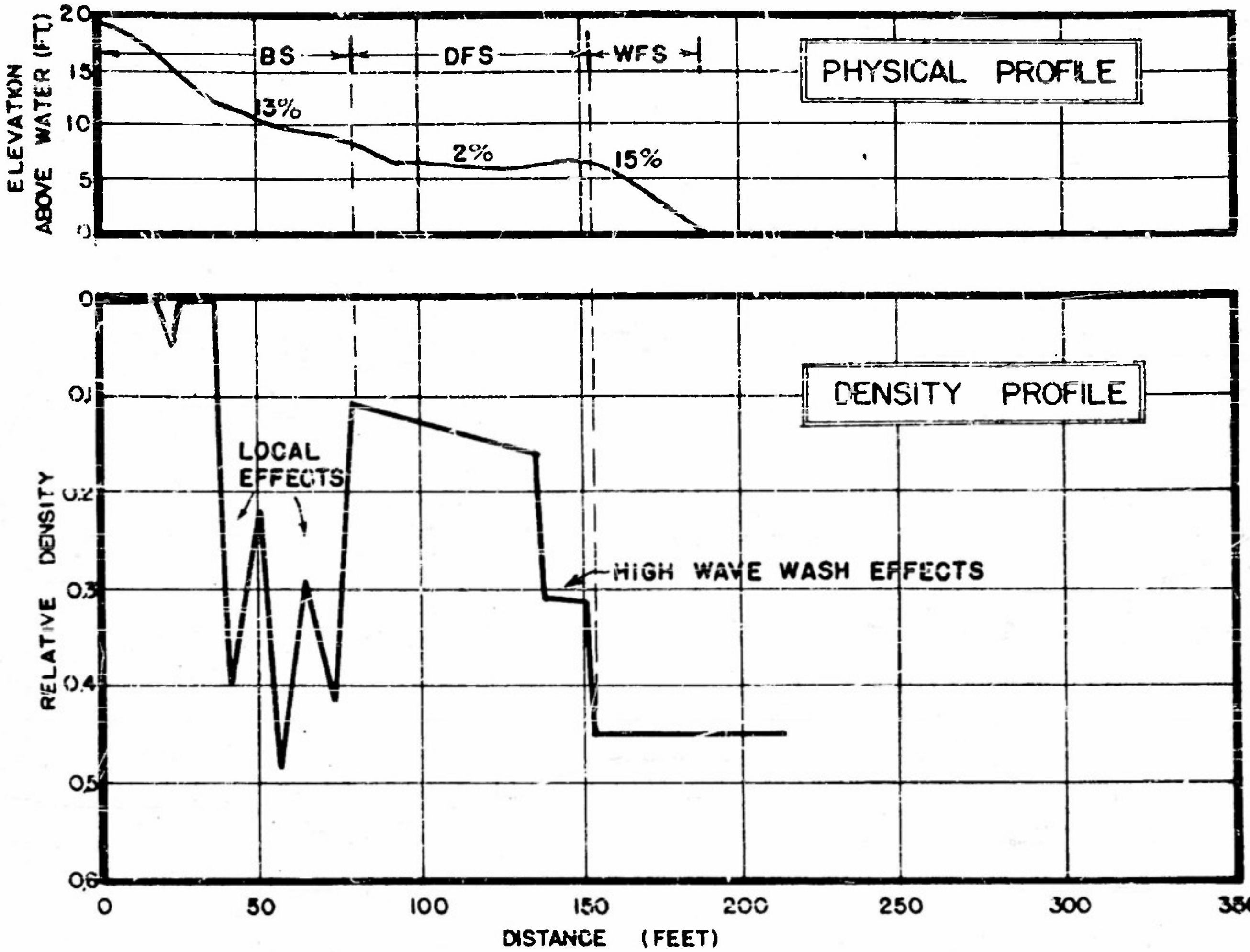


FIGURE 7

BEACH NO.	12 A
DATE	7 NOV. 53
SCALE:	1: 2500
D_{50}(DEC.):	1.60

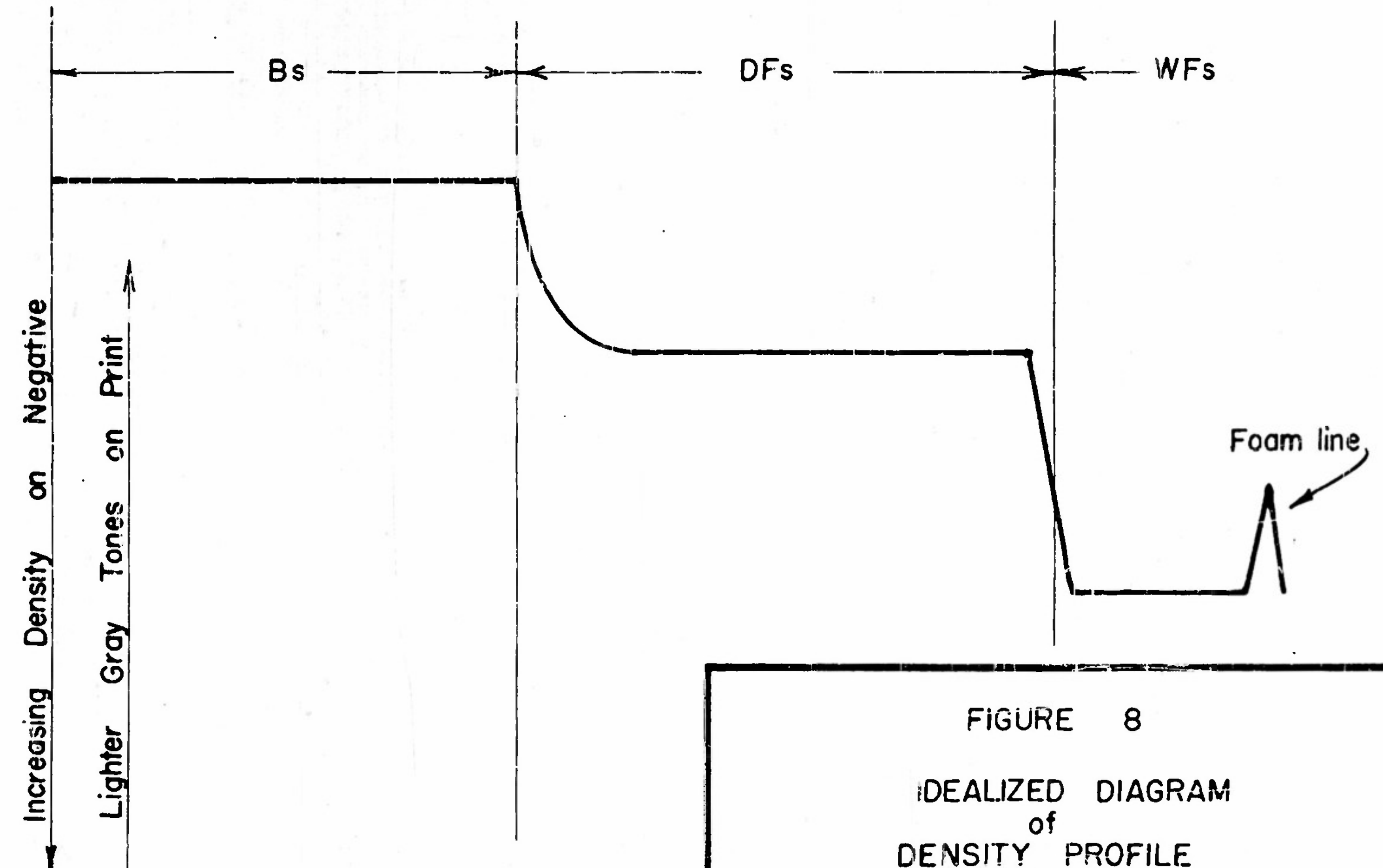


FIGURE 8

IDEALIZED DIAGRAM
of
DENSITY PROFILE
for
COARSE SAND BEACHES

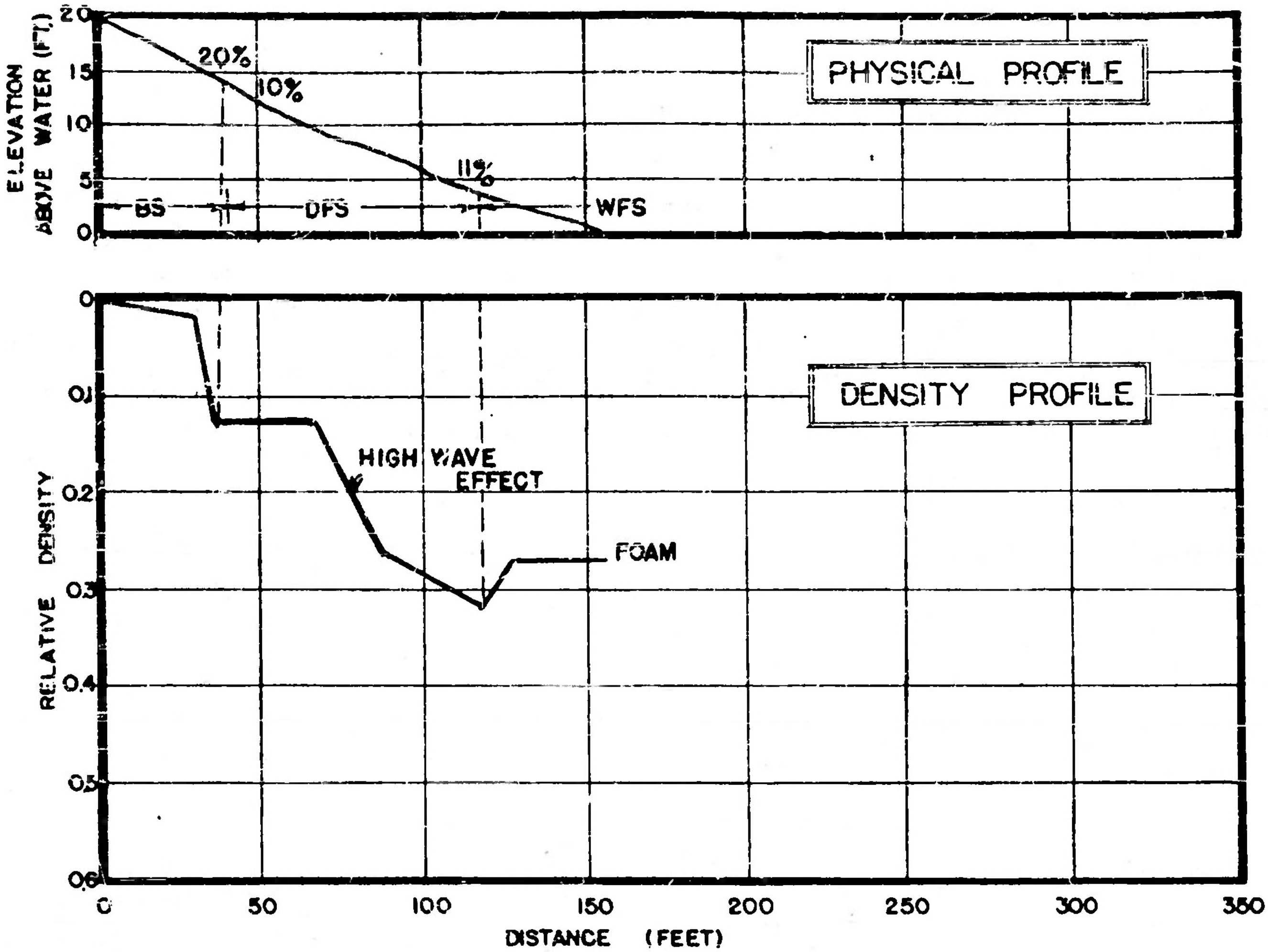


FIGURE 9

BEACH NO. 12 A
DATE 10 DEC 53
SCALE: 1:2500
D_{50}(DEC.): 1.60

GRAY TONE PATTERNS OF

FINE SAND BEACHES

The laboratory tests mentioned on the previous pages showed that fine sands ($D_{50} < 0.2$ mm.) would retain substantial amounts of surface moisture (up to 26% or 90% saturation)

The gray tone pattern of fine sand beaches is indicated by this fact. It should consist of:

1. A fairly uniform, light-toned area indicating the backshore with its negligible surface moisture contents (0-2%)

2. A band, sometimes very narrow, of rapidly increasing darkness indicating a rapid increase in surface moisture content at the backshore--foreshore boundary shading into

3. A relatively broad expanse, composed of narrow bands of gradually increasing darkness, indicating the increasing surface moistures of the drying foreshore. (The deepening of tone need not always be discernible to the naked eye.)

4a. A possible abrupt darkening of tone indicating abrupt change to near saturation at the wetted foreshore boundary

<u>or</u>

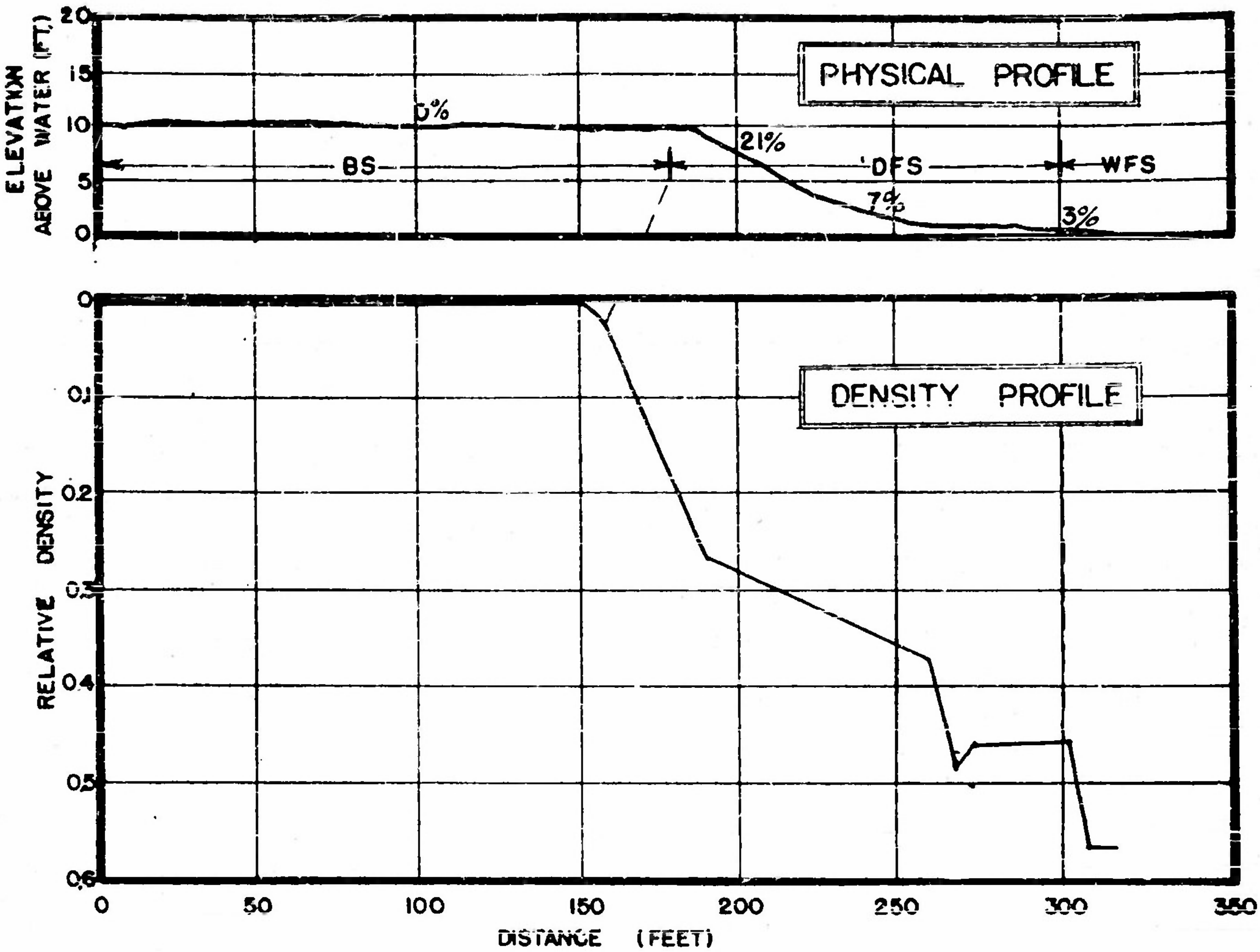
4b. A possible "leveling off" of tone indicating the same thing

5. A band, of variable width, having a fairly uniform dark tone indicative of the wetted foreshore with its nearly saturated sand (80-100%) and/or substantial expanse of free water surface.

This pattern was displayed, in general, by the fine sand beaches for which data was available. Figures 10 to 13 show typical density plots with their accompanying photographs and physical profiles. Figure 14 is schematic representation of an idealized density (gray-tone) profile.

There may be slight variations from the "typical" general pattern. For example, there may be abrupt tonal changes of substantial magnitude at both the backshore boundary and the wetted foreshore boundary. In contrast, the tonal changes at these points may consist of a "break" in density profile rather than a drop.

Also, the gradient of the density profile on the drying foreshore, i.e. the rate of tone deepening, is affected by relatively small differences in physical slope. This effect is indicated by Figure 15, showing the linear relationship between the slope of density profile and the slope of physical profile. Data for the preparation of Figure 15 was limited due to the selectvity involved. Only beaches having a falling tide below mid-tide stage were used. Beaches with insufficient or suspected physical data were not used. All relative densities were corrected according to the methods of Appendix B.



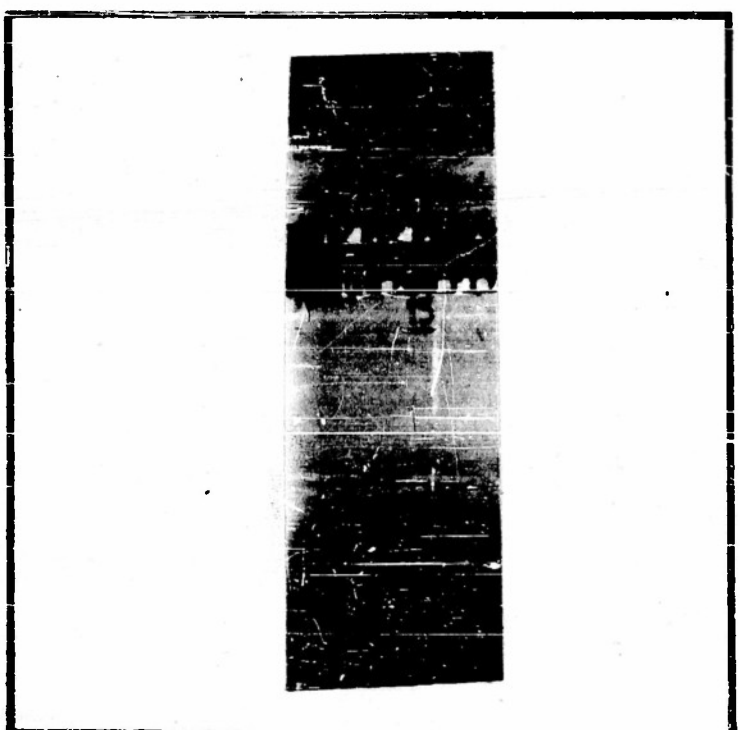


FIGURE 10

BEACH NO. 13
DATE 21 OCT. 53
SCALE: 1:2500
D_{50}(DEC.): 2.13
1.96

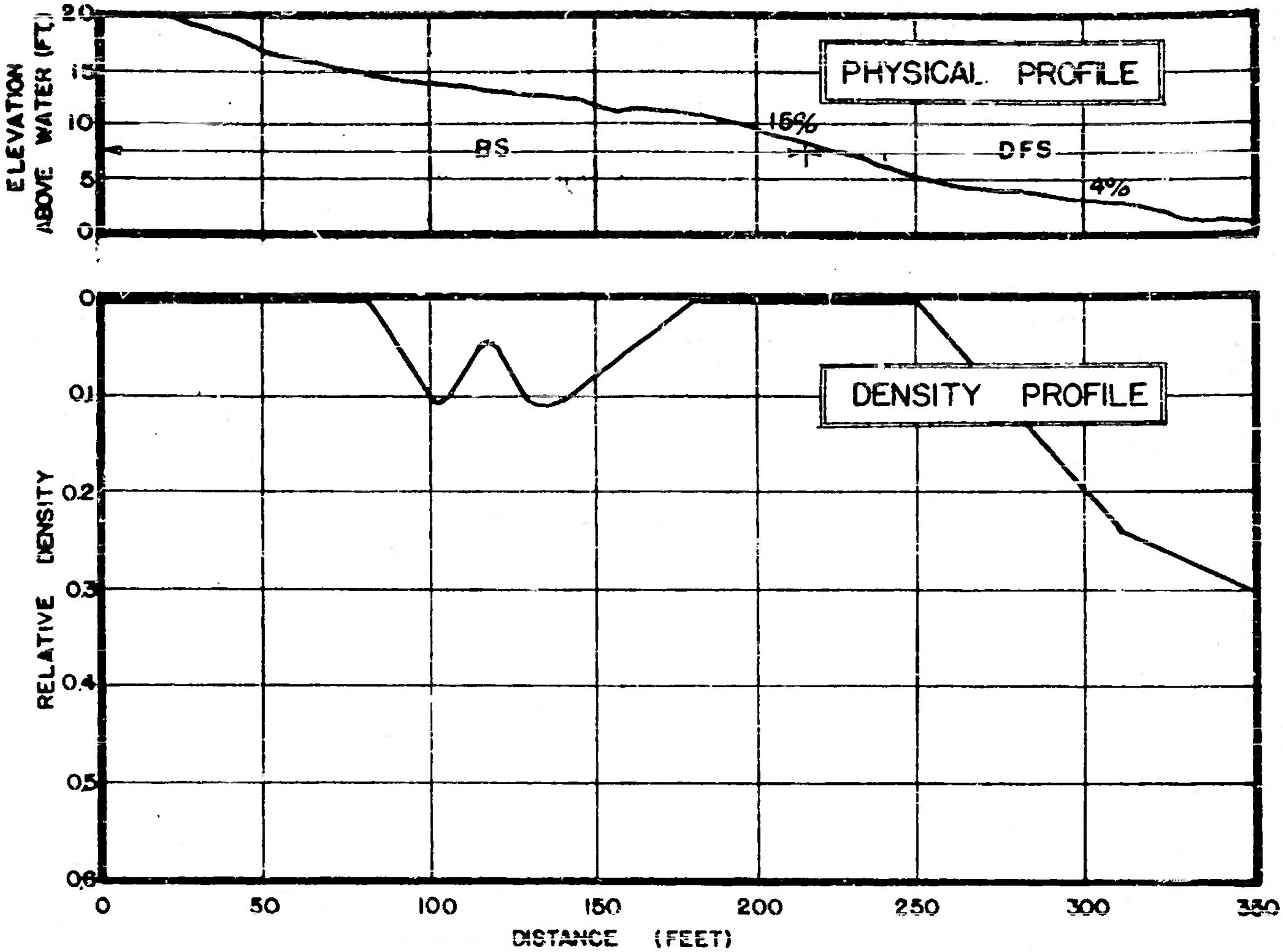
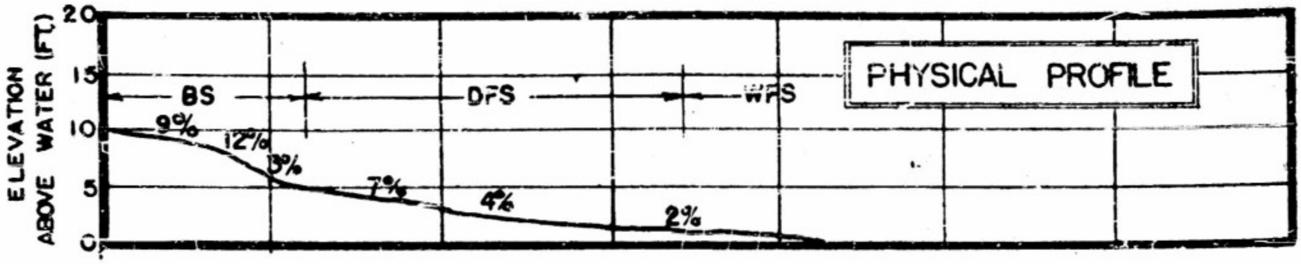


FIGURE 11

BEACH NO.	14
DATE	21 OCT 53
SCALE:	1 : 2500
D_{50}(DEC.):	1.90
	2.11



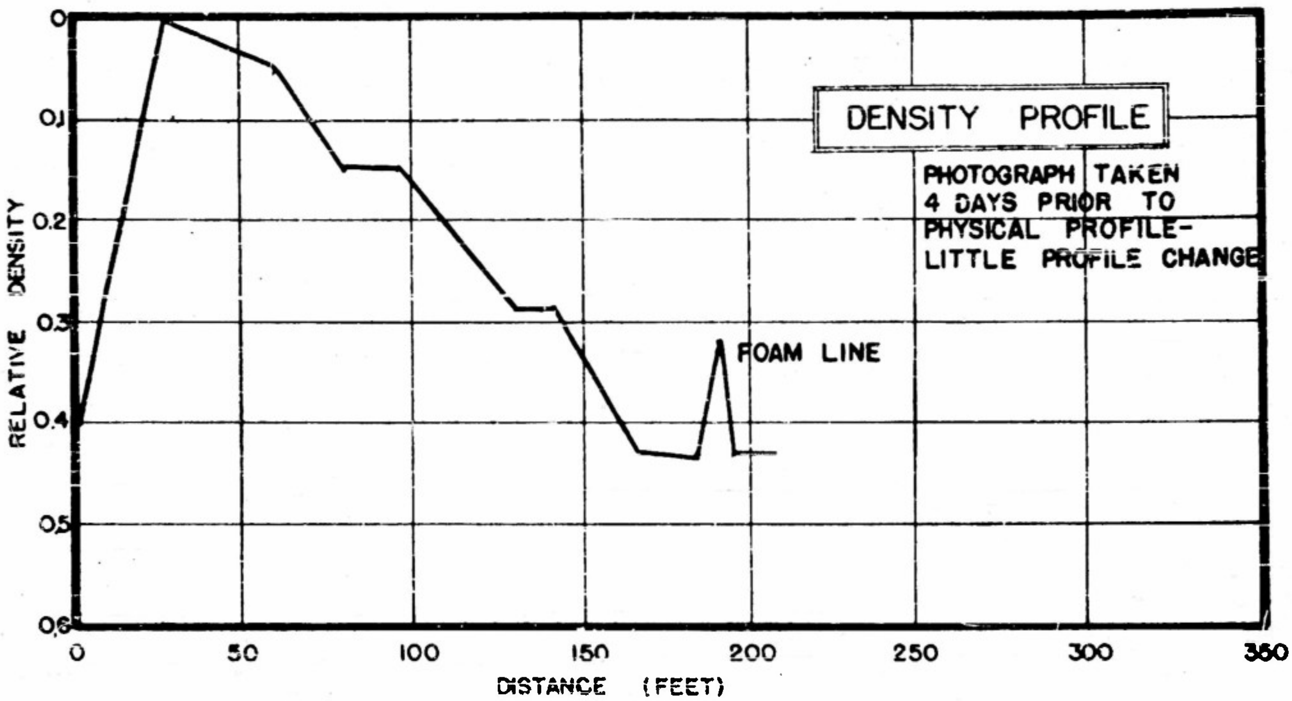


FIGURE 12

BEACH NO.	17A
DATE	17 DEC. 53
SCALE:	1:2500
D_{50}(DEC.):	2.10

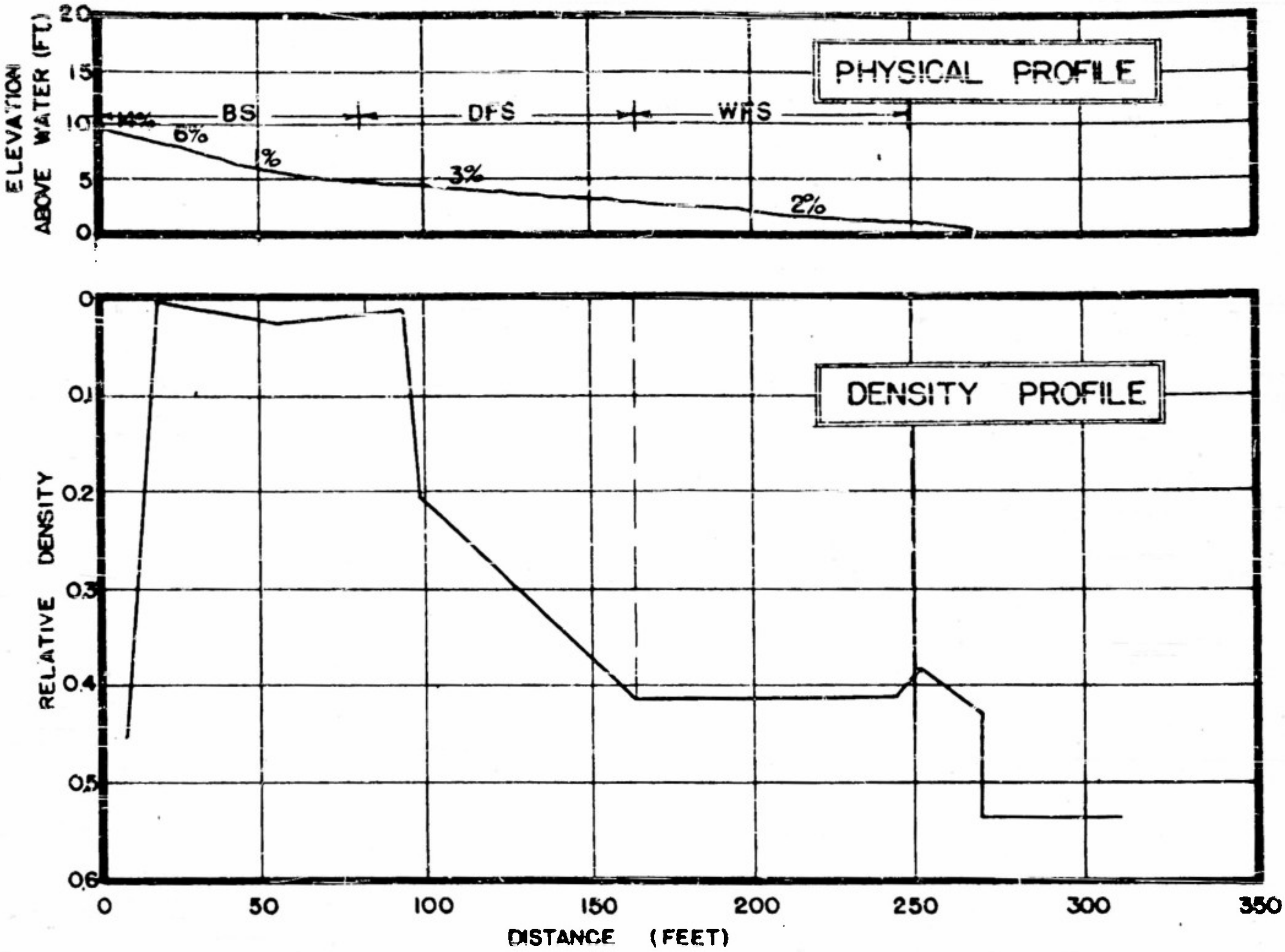


FIGURE 13

BEACH NO.	17 A
DATE	4 JAN. 53
SCALE:	1:2500
D_{50}(DEC.):	2.03
	2.09
	2,03

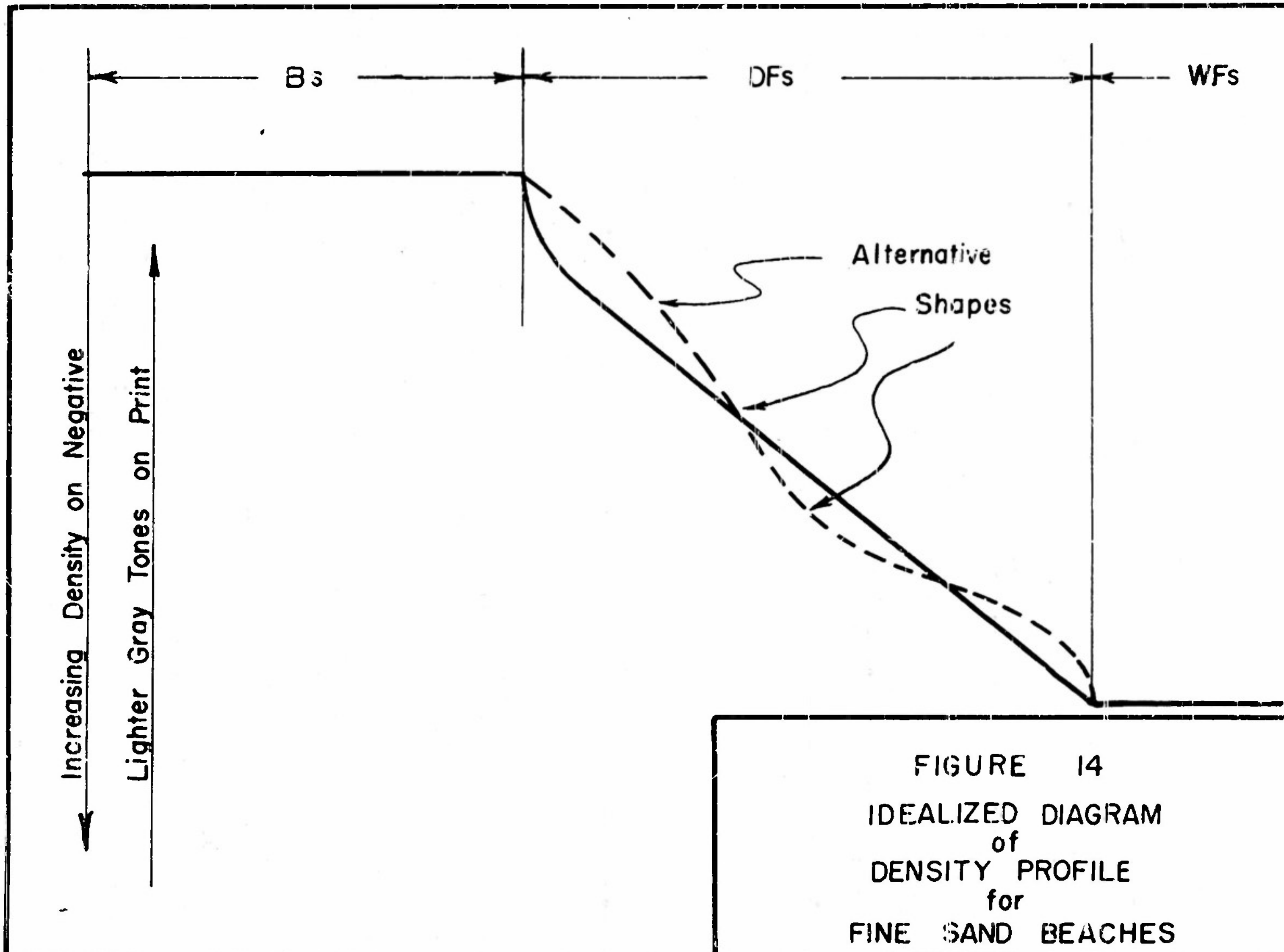


FIGURE 14

IDEALIZED DIAGRAM
of
DENSITY PROFILE
for
FINE SAND BEACHES

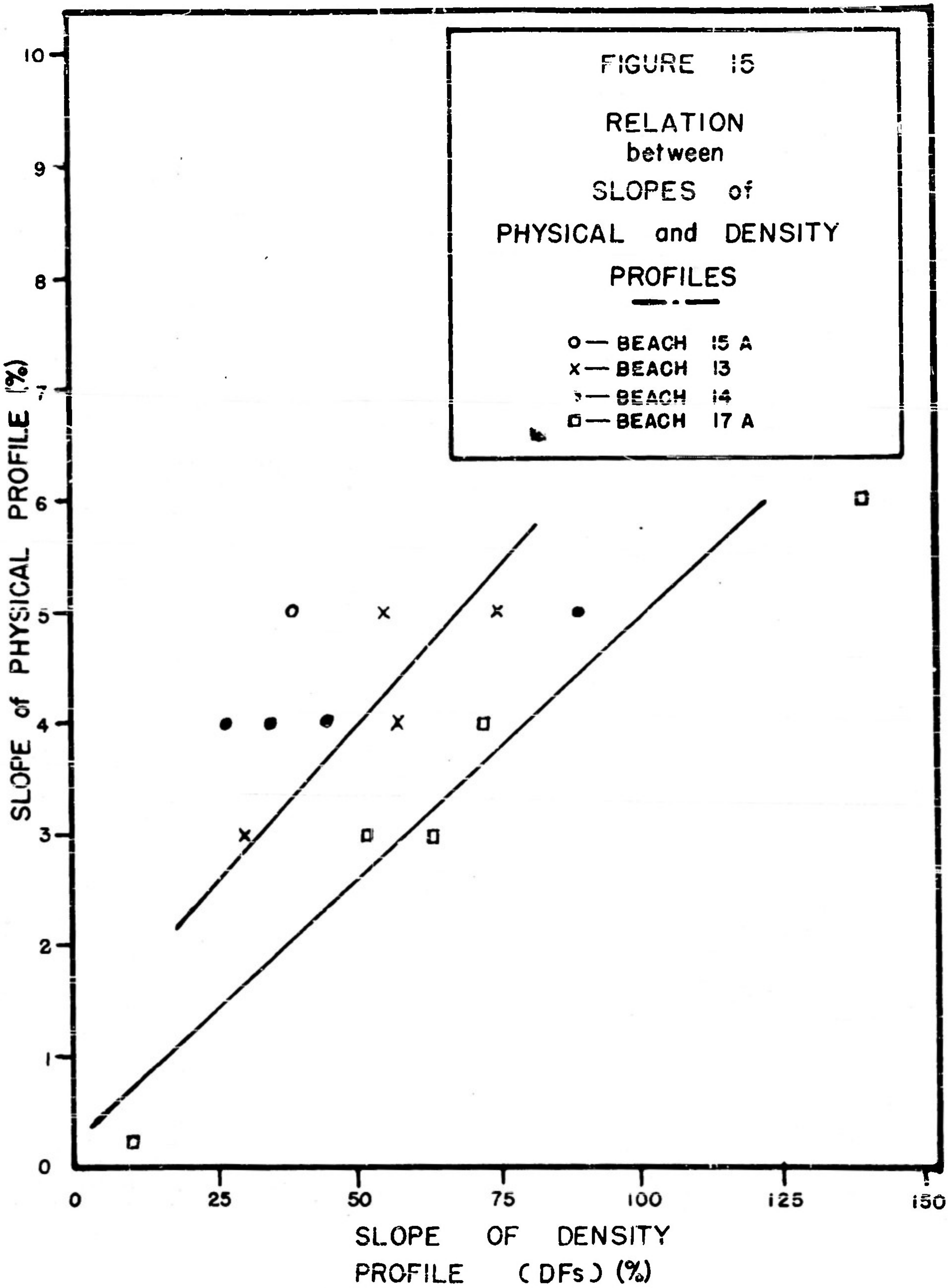


FIGURE 15
RELATION
between
SLOPES of
PHYSICAL and DENSITY
PROFILES
o — BEACH 15 A
x — BEACH 13
• — BEACH 14
□ — BEACH 17 A
SLOPE of PHYSICAL PROFILE (%)
0
1
2
3
4
5
6
7
8
9
10
0
25
50
75
100
125
150
SLOPE OF DENSITY
PROFILE (DFs) (%)

In summation, the gray tone pattern of the drying foreshore on a typical fine sand beach is characterized by a band of rapid darkening near the backshore boundary; a broad area composed of narrow bands with only slight adjacent contrast but a general tone darkening, approaching the waterline; a darker zone near the waterline representing the wetted foreshore. In general, the rate of tone darkening on the drying foreshore is proportional to the degree of physical slope. The tone of the drying foreshore is, for the most part, considerably darker than that of the backshore.

GRAY TONE PATTERNS OF MEDIUM SAND BEACHES

Unfortunately, photography below mid-tide and adequate coincident ground observations were not obtained for any beaches composed of medium sands (D_{50} = 0.175 mm. to 0.5 mm). All of the 50 photographic-observational sets that were finally available covered fine or coarse sand beaches or were above mid-tide level. Consequently, no density information was available on medium sand beaches.

It is to be expected that a medium sand beach will have a gray tone pattern intermediate between those of the fine and coarse beaches. The smaller medium sand grain-sizes (D_{50} = 0.2 mm to 0.3 mm.), able to hold surface moisture up to near saturation,* will have patterns resembling fine sand beaches. The larger medium sand grain-sizes (D_{50} = 0.3 mm. to 0.5 mm.), able to hold surface moisture up to saturations of 30-40%,* will have patterns resembling coarse sand beaches.

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* See Volume 4, this report for presentation of this data.

SECTION III

CONCLUSIONS

GENERAL

As mentioned in SECTION I, the conclusions listed in this section are based, for the most part, upon data included or describeed in this report. They should be considered as specific conclusions of the report — not necessarily as conclusions of the complete research program. Final conclusions of the complete research program, limited to pertinent details bearing upon the practical objectives of the program, will be found in Volume 5.

CONCLUSIONS

1. The gray-tones appearing on a sand beach with the exception of those due to vegetation and debris, indicate primarily the surface moisture present in the beach materials.

2. All other things being equal, the surface moisture is a function of the predominant grain-sizes of the material.

3. The gradation of gray-tones between completely saturated and completely dry sands is primarily a function of the predominant grain-sizes of the material.

4. The pattern of gray-tones, appearing on an aerial photograph of a beach, is indicative of the predominant grain-sizes of the material composing the beach. (Predominant grain-sizes are related to trafficability.*

5. The gray-tones of the dry backshore (0-10% saturation) and the wetted foreshore (80-100% saturation) may be assumed essentially constant for all beaches.** Accordingly, they may be considered as the upper and lower limits of the range of tones appearing on the drying foreshore.

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* See Volumes I, II, IV and V of this report.

** Of course backshores will be darker if recently wetted by rainfall. Also it is important to remember that the gray-tones appearing on a beach are functions of the exposure and development to which both the negative and print have been subjected. Since these will vary, the gray tones of both backshore and wetted foreshore. However, the relative gray tones, if computed correctly, may be considered the same. See Appendix B.

6. By eliminating the gray tones of the backshore and wetted foreshore, the gray tones appearing on the drying foreshore are the final indicators of predominant grain-sizes composing the beach.

7. The drying foreshores of beaches composed predominantly of fine materials ($D_{50} < 0.2$ mm) have gray tone patterns characterized by:

   a. A band of rapid darkening adjacent to the backshore boundary.

   b. A relatively broad expanse composed of narrow bands whose tones become gradually darker as the waterline is approached (the gradual darkening is not always discernible by eye).

   c. An abrupt darkening or leveling of tone near the waterline.

   This pattern is typically shown by Figure 16a.

8. The drying foreshores of sand beaches composed predominantly of coarse materials ($D_{50} > 0.5$mm.) have gray tone patterns characterized by:

   a. A band of rapid darkening adjacent to the backshore boundary.

   b. A relatively broad band, of fairly uniform tone, only slightly darker than the backshore.

   c. A narrow band or abrupt darkening of tone close to the waterline.

   The typical pattern is shown schematically by Figure 16b.

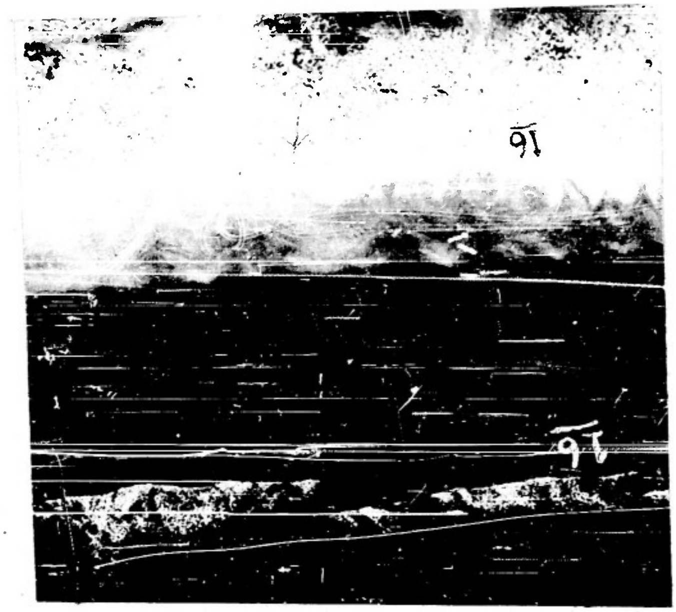

Figure 16a - Typical gray tone pattern of a fine sand beach.

Figure 16b - Typical gray tone pattern of a coarse sand beach.

9. Sand beaches composed of medium sands could not be analyzed due to lack of data. However, based upon laboratory tests reported in Volume IV, it is expected that:

   a. Gray tone patterns of beaches composed of the lower medium sizes (D_{50} = 0.2 to 0.3mm.) will resemble the patterns of fine sand beaches.

   b. Patterns of beaches composed of coarser materials (D_{50} = 0.3 to 0.5 mm.) will resemble those for coarse sand beaches.

10. The gray tone pattern on beaches composed of coarse materials is practically independent of physical slope.

11. The tone pattern on the drying foreshores of beaches composed of fine materials is affected by the physical slope, the rate of darkening increasing in direct proportion to the degree of slope.

12. When analyzing gray tone patterns, it is important that:

   a. The photography show the beach when the tide stage is below its mid-height.

   b. The backshore and wetted foreshore boundaries be carefully located.

   c. The local accumulations of seaweed and debris as well as other erratics be eliminated from the tone analysis.

13. The gray tone pattern may be modified near the waterline by the uprush due to high waves frequently interspersed among low waves. This uprush may cause a two-toned pattern for the wetted foreshore.

APPENDIX A

DESCRIPTION OF DATA

COLLECTION AND ANALYSIS METHODS

GENERAL

As mentioned previously, the original scheme for data collection contemplated the simultaneous - or near simultaneous collection of aerial photography, physical profiles, and representative beach samples, followed by controlled film development to a fairly constant gamma and quantitative comparison of micro-densitometric (transmissive) profiles.

For various reasons, beyond the control of the investigators, this ideal scheme required considerable revision, compromise and elimination. The information which follows pertains only to the revised methods of data collection and analysis.

DATA COLLECTION

The raw data consisted of two types:

1. Physical data
   a. Physical profile of beach
   b. Representative samples of beach material
2. Aerial photography

The physical profile of the selected test beaches was obtained by a ground observer at frequencies ranging from two to four times per week. Whenever possible, the profile was taken at times when the sea-levels were below mid-tide stage. Profiles were determined with the aid of an engineer's level and rod, according to standard procedures. Details are reported in Appendix A, Volume II.

Representative samples of the surface materials (0-3"), selected in accordance with the ground observer's judgment, were obtained for the backshore, drying foreshore, and wetted foreshore at the same time that the physical profile was completed.

Vertical aerial stereo photography was taken at frequencies ranging from one to four times per week, with frequent lapses, on each of the selected beaches. The photography was not necessarily completed on the same days as the physical profiles were taken. The photography was accomplished with standard aero filters, at scales of 1:2500 and 1:10000 between the hours of 1000 and 1400 with few exceptions. Occasional flights involving color, infra-red or Sonne photography were also completed. The film was forwarded, undeveloped to Cornell, complete (in most cases) with pertinent data regarding length, exposure, date, time, coverage and atmospheric conditions.

METHODS OF ANALYSIS

Following the receipt of field level notes and samples from the ground observer, the physical profiles were computed and plotted on cross-section paper and the samples were subjected to a mechanical analysis in accordance with the standard method adopted by the American Society for Testing Materials.

At first, attempts were made to control film development to a constant gamma. Film footages were carefully measured; density wedges were carefully exposed on the undeveloped rolls at four locations; chemicals, temperatures and times were controlled or their effect recognized. Unfortunately, the efforts were largely in vain. Development was essentially non-uniform even within a single roll. However, it was possible to obtain high gammas so that small differences in tone would be reflected by large differences in negative density.

Following development, the density wedge pointed closest to the aerial frame covering the test site, as well as a section of the frame covering the site, were cut out of the roll. Reference points for the calculation of relative densities were delineated on each section cut out. The wedges and frame sections then subjected to a measurement of micro-transmission densities proceeding in a direction perpendicular to the waterline, beginning at a point on the film corresponding to the actual backshore reference point used for observations on the ground. The micro-densitometer used for measurement had both automatic feed and automatic recording. A typical type record is shown on Figure 2.

The density-distance plot obtained from the micro-densitometer was averaged as shown by Figure 2. The densities of reference points were measured and the relative densities across the beach were computed in accordance with the method described in Appendix B.

Finally, density plots were compared in detail with the physical profiles and aerial photography. Erratics were eliminated, and representative density profiles determined. The position of the waterline at the time of photography was judged after determining the tide-level position at time of photography.

Whenever possible, slopes and adjacent contrasts on density plots were compared quantitatively.

APPENDIX B

METHODS FOR QUANTITATIVE COMPARISON OF DENSITY PROFILES FOR VARIOUS BEACHES

GENERAL

As mentioned in SECTION II, it was decided to attempt quantitative comparisons of density profiles for:

1. The same beach at different times
2. Different beaches at different times

To accomplish the objective, it was initially proposed that black and white reference panels be installed on each test beach and that photographs of all beaches be developed to a uniform gamma.

Both ideas proved impracticable. It was found to be excessively difficult to maintain the panels, while development to uniform gamma could not be achieved with the equipment available*. For example, it was found that gammas not only varied from roll to roll but also varied within the same roll. Despite great efforts to control development, even further efforts proved necessary, and the concept of uniform development was abandoned.

It was decided, instead, to base the density measurements upon mathematical manipulation of the actual density profiles. Two approaches were adopted. The first approach was based upon the assumption that gamma curves would be available for each roll of negatives. The second approach was based upon the assumption that the gammas would not be available. The mechanics, techniques and computations of each approach were conceived and executed for the most part, by Mr. Gunnar Simonsson.

* Standard motor-driven aerial roll film developer.

APPROACH BASED UPON THE AVAILABILITY OF GAMMA VALUES

Consider two points, A and B, on the ground. Let the inherent brightness of A = a and that of B = b. When a picture is taken of the ground, under uniform atmospheric conditions, it may be assumed safely that the intensities of light striking the negative from points A and B are proportional to their inherent brightnesses and that the exposure values, E, for the two points, are proportional to the intensities. For the two points, the significant relations can be expressed:

$$E_A = Ka$$
$$E_B = Kb$$

where K is the constant of proportionality for the negative.

The characteristic curve of a given negative shows the relations between densities on the negative and the logarithm of exposures required to produce those densities. The straight-line portion of the characteristic curve therefore has the equation $D = \gamma \log E$ where γ = gamma = the tangent of the angle between the straight-line portion of the curve and the horizontal. The densities of points A and B, then, are:

$$D_A = \gamma \log Ka$$
$$D_B = \gamma \log Kb$$

The density difference is:

$$D_A - D_B = \gamma (\log Ka - \log Kb)$$
$$= \gamma \log \frac{a}{b}$$

If γ is the same for all negatives of the same beach, the density difference for the two points should remain constant.*

If γ is different for different negatives then the quantity $\frac{D_A - D_B}{\gamma}$ should remain constant:

$$D_{A_1} - D_{B_1} = \gamma_1 \log \frac{a}{b}$$

$$D_{A_2} - D_{B_2} = \gamma_2 \log \frac{a}{b}$$

$$\log \frac{a}{b} = \text{constant} \quad \frac{D_{A_1} - D_{B_1}}{\gamma_1} = \frac{D_{A_2} - D_{B_2}}{\gamma_2}$$

Consequently, if γ is known for each negative, it is simple to manipulate the densities on one negative so that they can be compared to those on another. This is done by selecting one density difference as 100% and converting all other density differences to the same range. This can be done by using the simple ratio of gammas as a multiplier:

$$\frac{D_{A_1} - D_{B_1}}{\gamma_1} = \frac{D_{A_2} - D_{B_2}}{\gamma_2}$$

$$D_{A_2} - D_{B_2} = \frac{\gamma_2}{\gamma_1} (D_{A_1} - D_{B_1})$$

If $D_{A_1} - D_{B_1}$ be selected as unity (100%) it is not necessary to measure the density at any specific points on negative number two since the density differences between any two points need merely be multiplied by $\frac{\gamma_2}{\gamma_1}$ to expand (or contract) them so as to be comparable to the range $D_{A_1} - D_{B_1}$.

* See Footnote on next page.

APPROACH BASED UPON
ABSENCE OF RELIABLE GAMMA VALUES

This approach was founded upon the assumption that certain reference points close to the beach would maintain a roughly constant relative brightness*. The points required careful selection - the backshore surface, a dark road surface, the surface of a still deep water body, etc. If many points with well distributed brightnesses were chosen, it was felt that the comparison between different negatives of the same beach could be based upon the relation between the density differences of the selected reference points in all relevant combinations. This method is explained in the following paragraphs.

Let the densities of points A, B, C and D be denoted A, B, C and D. Then the density differences for various negatives of unknown gamma are denoted by the following table:

*Assuming that the intensities do not change differentially because of non-uniform atmospheric conditions and angles of sun-illumination. Even these may change - within limits- without appreciably affecting results.

Density Differences	Negatives			
	1	2	3	n
A - B	$(A-B)_1$	$(A-B)_2$	$(A-B)_3$	$(A-B)_n$
A - C	$(A-C)_1$	$(A-C)_2$	$(A-C)_3$	$(A-C)_n$
A - D	etc.	etc.	etc.	etc.
B - C				
B - D				
C - D				

In accordance with the previous section:

$$\frac{(A-B)_n}{\gamma_n} = \frac{(A-B)_1}{\gamma_1} \quad \text{and}$$

$$\frac{(A-B)_n}{(A-B)_1} = \frac{\gamma_n}{\gamma_1}$$

Also:

$$\frac{(A-C)_n}{(A-C)_1} = \frac{\gamma_n}{\gamma_1} \quad \text{and}$$

$$\frac{(A-B)_n}{(A-B)_1} = \frac{(A-C)_n}{(A-C)_1} = \frac{(B-C)_n}{(B-C)_1} = \text{etc.} = R\left(= \frac{\gamma_n}{\gamma_1}\right)$$

Assuming that a given negative has, because of unavoidable changes in brightness and errors of measurement, a range of R-values,

$$\text{let } R_m = \frac{R_{AB} + R_{AC} + R_{AD} + R_{BC} + \text{etc.}}{\text{number of relevant combinations}}$$

Assuming that all values of density are to be converted in such a manner that they can be compared to the range of values corresponding to negative n, then, in accordance with the previous section, the product $\lambda_x R_{m_x}$ should be constant where λ_x is the gamma (unknown) of any negative being converted and R_{m_x} is the average $\frac{\lambda n}{\lambda_x}$ based upon all relevant density combinations for the selected points on any negative (i.e. if $\frac{\lambda n}{\lambda_x}$ is a constant for all combinations on a given negative, then R_{m_x} is also a constant and any product of $\lambda_x R_{m_x}$ is constant). In most cases, the R-values for a given negative did not differ considerably from the R_m-value and the $\lambda_x R_{m_x}$ values did remain quite close (total range on one beach was 1.72 to 2.64 but most values lay within a range of 1.72 to 2.30)*.

If the R-values of a negative deviate considerably from the R_m-value, the most reliable density differences - and R-values - can be investigated.

The ideal value of the ratios $\frac{Rm_1 (A-B)_1}{(A-B)_n}$, $\frac{Rm_2 (A-C)_2}{(A-C)_n}$, etc. should equal one. If, instead, the ratios fluctuate considerably for a given density difference, say A-B, the density difference A-B is not reliable, i.e. A, B or both are bad points. By studying all other combinations having A and B it is possible to apportion appropriate weights to the various density differences and calculate a new R_m-value.

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* λ_x values were available in all cases and were used to check the accuracy of the proposed approach. Actually, the approach was not needed for the purposes of the project.

The quality of the above method for comparing densities on one beach with those of another depends upon the number and supply of good points. The more points that are used, the better the anticipated results, but the more time consuming is the determination. It is desirable that the brightness difference between the darkest and lightest points chosen, be as great as possible. Two additional points between these extremes may generally be considered sufficient for most determinations. The points should be carefully chosen to provide a large area of even brightness which will not fluctuate greatly. Of course, when two or more beaches are compared, the reference points are not the same and the results of measurements may be expected to diverge from the ideal. However, if the points are of analogous types, bituminous road surfaces, dry beach areas, still-water surfaces, etc. it has been found that the method can be utilized effectively.

Of course, the method based upon available gamma-values is the best. It is important, however, if this method is used, to investigate the range of densities for the beach points in relation to the shape of the characteristic curve. If these densities fall on a curved line portion of the curve, the density differences for the beach should be figured directly from the curve.

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